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(71) Applicant (*for all designated States except US*): **FEDERAL SIGNAL CORPORATION** [US/US]; 1415 West 22nd Street, Regency Towers, Suite 1100, Oak Brook, Illinois 60523-2004 (US).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): **CZAJKOWSKI, Robert, A.** [US/US]; 7709 W. 174th Street, Tinley Park, Illinois 60477 (US).

(74) Agents: **FILBIN, Paul, J.** et al.; LEYDIG, VOIT & MAYER, LTD., Two Prudential Plaza, Suite 4900, 180 N Stetson St, Chicago, Illinois 60601-6780 (US).

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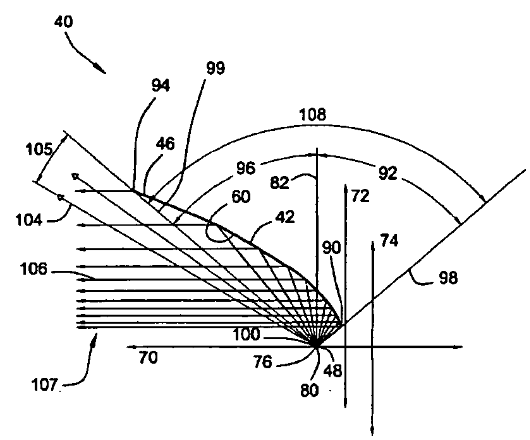

(57) Abstract: A light assembly is disclosed which can include an LED array and a reflector (46). The LED array can include a plurality of LEDs (48) which are disposed such that each LED (48) is substantially aligned to define a focal axis (100). Each LED can emit light substantially along an optical output axis (82), with each optical output axis (82) being perpendicular to the focal axis (100). The optical output axis (82) of the LED array can be disposed in intersecting relationship with the reflector surface (46). The reflector (46) can be defined by a curve section defined with respect to a principal axis (70). The principal axis (70) and the output axis (82) of the LED array can be in non-parallel relationship with each other. The optical output axis (82) of the LED array can be substantially perpendicular to the principal axis (70) of the curve section of the reflector.

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LIGHT ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 60/510,192 filed October 10, 2003, which is incorporated in its entirety herein by this reference.

FIELD OF THE INVENTION

[0002] This invention relates in general to light assemblies, and more particularly to a light assembly which includes a light-emitting diode (LED).

BACKGROUND OF THE INVENTION

[0003] The light output of an LED can be highly directional. This directionality has been a detriment when trying to couple LEDs with conventional parabolic reflectors. The directionality of an LED, taken together with the desire to shape the light output in different and sometimes opposite ways to yield a desired performance specification, has resulted in LED lighting systems that frequently employ lens elements in addition to reflectors to shape the beam. These LED-lens-reflector systems can suffer from poor optical efficiency. U.S. Patent No. 6,318,886 describes a method whereby a beam pattern is produced with LED light sources and a variation of a conventional reflector.

SUMMARY OF THE INVENTION

[0004] The invention provides a light assembly that can include an LED and a reflector. The LED is disposed with respect to the reflector such that an optical output axis of the LED is in offset, intersecting relationship to a principal axis of a reflective surface of the reflector such that the output axis is in non-parallel relationship with the principal axis of the reflective surface. The reflective surface can include a linear curved section. The curved section can be defined by a parabolic equation. The relationship between the LED and the reflective surface can facilitate beam shaping and improve light collection efficiency.

[0005] The reflector can take advantage of the directionality of the LED to orient and direct substantially all the light from the LED to the areas where it is desired and at light

output levels appropriate to each area. As a result, the reflector design of the invention can have extremely high optical efficiency.

[0006] These and other features of the present invention will become apparent to one of ordinary skill in the art upon reading the detailed description, in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIGURE 1 is an elevational view of an LED useful in connection with the present invention;

[0008] FIG. 2 is a graph of relative intensity (percentage) versus angular displacement (degrees) for a LED;

[0009] FIG. 3 is a sectional view of a conventional light assembly including a conventional reflector and an LED depicted somewhat schematically as a point source;

[0010] FIG. 4 is a sectional view of a light assembly according to the present invention, including a parabolic reflector surface and an LED depicted somewhat schematically as a point source;

[0011] FIG. 5 is a perspective view of the light assembly of FIG. 4;

[0012] FIG. 6a is an isocandela plot of the light output of the light assembly of FIG. 4;

[0013] FIG. 6b is a cross-sectional view taken along line 6B-6B in FIG. 6a of the light output of the light assembly of FIG. 4;

[0014] FIG. 6c is a cross-sectional view taken along line 6C-6C in FIG. 6a of the light output of the light assembly of FIG. 4;

[0015] FIG. 7 is a perspective view of another embodiment of a light assembly according to the present invention;

[0016] FIG. 8a is an isocandela plot of the light output of the light assembly of FIG. 7;

[0017] FIG. 8b is a cross-sectional view taken along line 8B-8B in FIG. 8a of the light output of the light assembly of FIG. 7;

[0018] FIG. 8c is a cross-sectional view taken along line 8C-8C in FIG. 8a of the light output of the light assembly of FIG. 7;

[0019] FIG. 9 is another embodiment of a light assembly according to the present invention;

[0020] FIG. 10a is a isocandela plot of the light output of the light assembly of FIG. 9;

[0021] FIG. 10b is a cross-sectional view taken along line 10B-10B in FIG. 10a of the light output of the light assembly of FIG. 9;

[0022] FIG. 10c is a cross-sectional view taken along line 10C-10C in FIG. 10a of the light output of the light assembly of FIG. 9;

[0023] FIG. 11 is an exploded view of another embodiment of a light assembly according to the present invention;

[0024] FIG. 12 is a front elevational view of the light assembly of FIG. 11;

[0025] FIG. 13 is a cross-sectional view taken along line 13-13 in FIG. 12 of the light assembly of FIG. 11;

[0026] FIG. 14 is a cross-sectional view taken along line 14-14 in FIG. 12 of the light assembly of FIG. 11;

[0027] FIG. 15a is an isocandela plot of the light output of the light assembly of FIG. 11;

[0028] FIG. 15b is a cross-sectional view taken along line 15B-15B in FIG. 15a of the light output of the light assembly of FIG. 11; and

[0029] FIG. 15c is a cross sectional view taken along line C-C in FIG. 15a of the light output of the light assembly of FIG. 11.

[0030] FIG. 16 is a table associated with a combined light output specification comprising a combination of standards wherein the highest value for a particular location is selected as the value for the combined specification.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0031] Referring to FIGS. 1 and 2, the spatial radiation pattern from a typical high output LED 25, in this case a Lumileds Luxeon® LED, along with a graphical representation of the light output of the LED 25 is shown by way of a plurality of arrows 27 with the length of the arrow 27 corresponding to the relative light intensity output for the LED at that location. The radiation pattern clearly demonstrates that the highest light output occurs at approximately 40° from both directions from an optical output axis 30 of the LED (shown in FIGS. 1 and 2 as a 0° axis), and that the majority of the light is produced within 60° from both directions from the output axis 30. The output axis 30 can extend substantially through the center of the face of the lens of the LED through a virtual focal point 32 of the LED. Since the die that produces the light in the LED is a finite size, the virtual focal point 32 can be a theoretical point within the LED where the majority of the light rays being emitted by the die appear to

originate. It is also apparent from FIGS. 1 and 2 that the spatial light output characteristics of the LED are independent of color.

[0032] FIG. 3 shows the amount of light from an LED that is captured by a conventional reflector system, and FIG. 4 shows the amount captured by a reflector system according to the present invention. As shown in FIGS. 3 and 4, the inventive reflector system can capture and redirect a significantly greater amount of light from an LED than from the same LED used in a conventional parabolic reflector system.

[0033] Referring to FIG. 5, an embodiment of a light assembly 40 according to the present invention is shown. The light assembly 40 can include a reflector 42 and an LED array 44. The reflector 42 includes a reflective surface 46. The LED array 44 includes a plurality of LEDs 48. In this embodiment, the LEDs 48 are arranged in three sets 51, 52, 53 of three LEDs each, for a total of nine LEDs 48. An example of a suitable LED for use in the present invention is the Lumileds Luxeon® LED as discussed in U.S. Patent Application No. 10/081,905, filed on February 21, 2002, and entitled "LED Light Assembly," the entire contents of which are incorporated herein by reference. The light assembly 40 can also include other components, such as, a power supply and a heat sink, for example.

[0034] The LEDs 48 are placed in substantially aligned relationship with each other such that their virtual focal points are substantially aligned along an axis. As a result, the optical output axis of each LED 48 is also similarly aligned, thereby defining a virtual focal point axis 100. In this embodiment, there are nine optical output axes 30 that are disposed is substantially perpendicular relationship to the virtual focal point axis at the virtual focal of each LED 48. It will be understood that in other embodiments, the light assembly can include a single LED or a different number of LEDs.

[0035] Referring to FIG. 3, in a conventional reflector system the reflector 54 can comprise at least a portion of a paraboloid of revolution about a principal axis 55. The LED or LED array 56 is disposed such that its optical axis is substantially aligned with the principal axis 55 of the reflector 54.

[0036] Referring to FIG. 4, the reflective surface 46 includes a linear curved section 60. In this embodiment, the curved section 60 is parabolic. The equation for the parabolic curve in this example is: $y^2 = 1.22\,x$, where x is taken along a horizontal principal axis 70 of the parabolic section 60 and y is taken along a vertical y axis 72 which is perpendicular to the principal axis 70. The y axis 72 is parallel to a directrix 74 of the parabolic section 60. A focus 76 of the parabolic section 60 is disposed coincident with the virtual focal point axis 80

of the LED array. The output axis 82 of the LED array is substantially parallel with the y axis 72 and the directrix 74 of the parabolic section 60. The size of the parabolic curve can be based upon the angular limits of the light output of the LED array and the physical size constraints of the application in which the light assembly is intended to be used, for example.

[0037] In this example, a first end 90 of the parabola 60, which is closest to the LED 48, is at a first angle 92 from the output axis 82, while a second end 94, which is furthest from the LED 48, is at a second angle 96 from the output axis 82. The first angle 92 is measured between the output axis 82 and a line 98 extending between the focal point axis 80 and the first end 90. The second angle 96 is measured between the output axis 82 and a line 99 extending through the focal point axis 80 and the second end 94. In this embodiment, the first angle 92 is equal to 60°, and the second angle 96 is equal to 50°.

[0038] The ends 90, 94 can constitute a compromise between physical size and maximum light collection, as most of a conventional LED's light output is typically concentrated between these two angular values (see FIG. 1.). From these constraints an infinite number of parabolic curves can be created. The parabolic curve is fully constrained by placing the first endpoint 90 of the curve nearest to the LED vertically above the highest point of the LED's structure. This placement will ensure that the light reflected from this endpoint 90 will be substantially unimpeded by the LED housing. In other embodiments, the reflector can have a parabolic section with one or both of the ends disposed in different locations

[0039] Referring to FIG. 5, to construct the reflective surface 46, the parabolic curve section 60 is swept along the focal axis 100 to create the reflective surface. The focal axis 100 is placed coincident with the focus of the curve section 60 and perpendicular to a plane of the curve through the principal axis 70 and the y axis 72, as shown in FIG. 4. Referring to FIG. 5, the LEDs 48 are disposed in a linear array with their virtual focal points coincident with the focal axis 100.

[0040] Referring to FIG. 4, substantially all of the light emitted from the LED array is directed toward the reflector 42 such that substantially all of the light emitted from the LED array contacts the reflective surface 46 and is reflected by the same, the light being substantially collimated by the reflective surface 46. Only a portion 104 of the light emitted by the LED array is unreflected by the reflector 42. In this embodiment, the portion 104 of unreflected light emitted by the LED array is disposed in a 10° arc segment 105 adjacent the arc segment defined by the second angle 96. The vertical vector component of all the light rays 106 leaving the LED that hit the reflector, i.e., the light emitted in the area covered by

the arc segments defined by the first angle 94 and the second angle 96 (a 110° arc segment 108 in this example), is directed to the front 107 of the assembly 40 due to the parabolic shape of the reflective surface 46 while the non-vertical vector components of the rays are unchanged. This results in a light beam 110 that is very narrow in a vertical direction 112 but quite wide in a horizontal direction 114, as shown in FIG. 6. Referring to FIG. 6, the light output is shown in the form of an isocandela plot with graphs to the right and below it that show cross-sections through the light beam 110.

[0041] Referring to FIG. 7, another embodiment of a light assembly 140 according to the present invention is shown. The light assembly 140 includes a reflector 142 and an LED array 144. The reflector 142 can include a reflective surface 146 having a plurality of reflective portions 221, 222, 223, 224, 225, 226, 227, 228, 229. The number of reflective portions can correspond to the number of LEDs 148 included in the light assembly 140. In this case, the LED array 144 includes nine LEDs 148. Each reflective portion can be defined by a parabolic curve section which is rotated over a predetermined arc about its principal axis to form a part of a paraboloid. The parabolic curve section can be the same as the parabolic curve section 60 of the reflector 42 of FIG. 4.

[0042] Referring to FIG. 7, the size of each reflective portion 221, 222, 223, 224, 225, 226, 227, 228, 229 can be related to the spacing of adjacent LEDs 148 with the principal axis of a particular reflective portion extending through the virtual focal point of the LED with which the particular reflective portion is associated. The extent of each reflective portion along the focal axis 200 can be delineated by its intersection with the reflective portions immediately adjacent thereto. For example, the fourth reflective portion 224 can include a parabolic section 160 that is rotated about its principal axis 170 over a predetermined arc 178. The end points 184, 185 of the arc 178 are defined by the points where the arc 178 intersects the arcs 186, 187 of the adjacent third and fifth reflective portions 223, 225, respectively. The outer extent of each end reflective portion 221, 229 preferably extends far enough to capture substantially all the light being emitted by the respective end LED 148a, 148b in a respective outer direction 230, 231 along the focal axis 200.

[0043] The reflective surface 146 can extend all the way to a plane 234 defined by the LED mounting. The light rays leaving the LED array 144 that hit the reflector 142 can be directed to the front 236 of the assembly 140 by the parabolic shape of the reflective surface 146. This reflector 142 can result in a beam of light 210, as shown in FIG. 8, that is narrower and more concentrated than the light beam 110 shown in FIG. 6. The light beam 210 can be

suitable for applications that require a "spot" style beam. The light assembly 140 of FIG. 7 can be similar in other respects to the light assembly 40 of FIG. 5.

[0044] Referring to FIG. 9, another embodiment of a light assembly 340 according to the present invention is shown. The light assembly 340 of FIG. 9 includes a reflector 342 and an LED array 344. The reflector 342 includes a reflective surface 346. The LED array 344 includes a plurality of LEDs 348. The reflective surface 346 has a body portion 354 flanked by two end portions 356, 357. The body portion 354 includes a parabolic section that is similar to that of the reflector 42 of the light assembly 40 of FIG. 5. Each end portion 356, 357 can be defined by rotating a parabolic curve about its principal axis over a predetermined arc. The principal axis of the parabolic curve of each end portion 356, 357 can intersect the optical output axis 382 of the end LED 348a, 348b with which the respective end portion 356, 357 is associated.

[0045] The reflector 342 of FIG. 9 can be useful in that it can produce a light beam 310 that can satisfy the current National Fire Protection Association (NFPA) and the General Services Administration emergency warning light specifications, which are incorporated herein by reference. The body portion 354 can produce a wide horizontal light distribution 311, as shown in FIG. 10. The end portions 356, 357 can produce a narrow, high intensity light distribution 312 visible in the center of the isocandela plot shown in FIG. 10. The current invention can use the light distribution characteristics of the LED array and the configuration of the reflective surface to provide controlled beam shaping for meeting a predetermined specification.

[0046] Referring to FIGS. 11-14, another embodiment of a light assembly 440 according to the present invention is shown. FIG. 15 shows the light output characteristics of the light assembly 440 of FIG. 11. Referring to FIG. 11, the light assembly 440 can include a reflector 442, an LED array 444 disposable within the reflector 442, an LED power supply board 445 mounted to the reflector 442 and electrically connected to the LED array 444, and a heat sink 449 mounted to the reflector 442 and operably arranged with the LED array 444.

[0047] Referring to FIGS. 12-14, the reflector 442 can include a housing 454 which defines an opening 455 and an interior cavity 456. The reflector 442 can include a reflective surface 446 which acts to define a portion of the cavity. The LED array 444 can be disposed within the cavity 456 of the reflector 442. The heat sink 449 can be mounted to an underside of the reflector such that the LED array 444 is in overlapping relation therewith. The LED

power supply board 445 can be mounted to the reflector 442 adjacent a rear end 450 thereof. The rear end 450 can oppose the opening 455 of the reflector 442.

[0048] Referring to FIG. 12, the reflective surface 446 includes a body portion 457 and two flanking end portions 458, 459. Referring to FIG. 13, the body portion 457 can include a parabolic curve section 460 comprising a plurality of parabolic curve segments 461, 462, 463, 464. In this embodiment, the body portion 457 includes four parabolic curve segments to define the parabolic curve section. The four parabolic segments 461, 462, 463, 464 of the body portion 457 can each be defined by a different parabolic equation. The segments abut together to define the parabolic curve section 460 and establish discontinuities 465, 466, 467 therebetween. The parabolic curve section 460 can be extended along the focal axis 400 over a predetermined amount to define the body portion 457. The parabolic curve segments 461, 462, 463, 464 can have different principal axes.

[0049] In other embodiments, two or more segments of a curve section can abut together substantially without any discontinuity therebetween. In other embodiments, the two or more of the segments can have the same parabolic equation. In yet other embodiments, two or more of the segments can have the same principal axis.

[0050] The size and shape of each parabolic curve segment can be determined through an iterative process of creating a surface, performing a computer ray trace simulation of the surface, comparing the results to a predetermined specification, modifying the surface, and repeating the preceding steps until a surface which substantially matches or exceeds the specification is found. The reflective surface associated with each of these parabolic curve segments can direct light to a specific spatial area.

[0051] Referring to FIG. 14, the second end portion 459 can include a parabolic curve section 484 comprising a plurality of parabolic curve segments 485, 486, 487, 488, 489. In this embodiment, the curve section 484 of the second end portion 459 includes five parabolic curve segments. The parabolic curve segments 485, 486, 487, 488, 489 can be defined by different parabolic equations. The segments of the end portion 459 can be joined together in a manner similar to how the parabolic segments of the body portion 457 are joined. The second end portion 459 can be defined by rotating the parabolic curve segments 485, 486, 487, 488, 489 about their respective principal axes over a predetermined arc between the abutting edge 498 of the body portion 457 and the opening 470 of the reflector 442. The first end portion 458 is similar to the second end portion 459, the first end portion being a mirror

image of the second end portion. In other embodiments, the first and second end portions can be different from each other.

[0052] Referring to FIG. 15, the combined effect of the body portion and the first and second end portions of the reflector of FIG. 12 is to produce a light distribution pattern 410 capable of meeting a predetermined lighting performance specification. Referring to FIG. 16, the lighting performance specification shown in the "Combined" table constitutes a composite specification. For this embodiment, a composite specification was created from two or four (depending on color) existing industry specifications to yield the light distribution pattern as shown in FIG. 15. The following industry standards were used to generate the composite specification: the "Federal Specification for the Star-of-Life Ambulance," KKK-A-1822D (November 1994), propounded by the General Services Administration; NFPA 1906 (2001 edition), standard for "Wildland Fire Apparatus," propounded by the NFPA; J595 and J845 standards, propounded by the Society of Automotive Engineers (SAE); and California Title 13, Class B standard, propounded by the State of California. The composite specification includes, for each particular location specified, the highest light value specified in the foregoing standards. The values of the various standards can be converted into a uniform unit of measurement, candelas, for example, to make the described comparison.

[0053] Thus, the exemplary embodiments of the present invention show how the reflective surface of the reflector can be configured to provide very different light output characteristics. This ability is highly desirable since optical performance specifications vary widely within the various lighting markets. While only some variations based on parabolic cross sections of the reflector are illustrated, an infinite number of variations can be developed to meet a required beam distribution. It should be noted that the base curve of the reflector is also not limited to parabolic cross sections. Other curves such as hyperbolic, elliptic, or complex curves can be used.

[0054] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference

[0055] The use of the terms "a" and "an" and "the" and similar referents in the context of describing the invention is to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided herein is intended to illuminate the invention and does not pose a limitation on

the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0056] Preferred embodiments of this invention are described herein. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

WHAT IS CLAIMED IS:

1. A light assembly comprising:

an LED, the LED operable to emit light substantially along an optical output axis; and

a reflector, the reflector having a reflective surface, the reflective surface including a curve section, the curve section being disposed in predetermined relationship relative to a principal axis, the principal axis being in non-parallel relationship with the optical output axis.

2. The light assembly according to claim 1 wherein the principal axis is substantially perpendicular to the optical output axis.

3. The light assembly according to claim 1 wherein the LED has a virtual focal point, the optical output axis extending through the virtual focal point, and the principal axis extending through the virtual focal point.

4. The light assembly according to claim 1 further comprising an array of LEDs.

5. The light assembly according to claim 4 wherein each LED includes a virtual focal point, the LEDs being disposed such that the virtual focal points extend along a focal axis.

6. The light assembly according to claim 5 wherein the virtual focal points are substantially aligned with each other.

7. The light assembly according to claim 4 further comprising a power supply operably arranged with the LED array such that the LED array is selectively operable to emit light.

8. The light assembly according to claim 7 further comprising a heat sink operably arranged with the LED array.

9. The light assembly according to claim 1 wherein the curve section comprises a

parabolic curve section.

10. The light assembly according to claim 9 wherein the parabolic curve section is defined by a parabolic equation, the parabolic equation being $y^2 = nx$, where x is taken along the principal axis, y is taken along a y axis perpendicular to the principal axis, and n is a predetermined coefficient.

11. The light assembly according to claim 10 wherein the y axis is substantially parallel to the optical output axis.

12. The light assembly according to claim 10 wherein the parabolic curve section has a focus, the LED has a virtual focal point, the focus being disposed substantially coincident to the virtual focal point.

13. The light assembly according to claim 9 wherein the LED includes a virtual focal point, the optical output axis extending through the focal point, the parabolic curve section includes a first end and a second end, the first and second ends disposed in relation to the LED such that substantially all of the light emitted from the LED contacts the reflective surface.

14. The light assembly according to claim 13 wherein the first end and the virtual focal point defining a first line, the first line and the optical output axis defining a first angle, the second end and the virtual focal point defining a second line, the second line and the optical output axis defining a second angle.

15. The light assembly according to claim 14 wherein the first angle is different than the second angle.

16. The light assembly according to claim 15 wherein the first angle is approximately 60°, and the second angle is 50°.

17. The light assembly according to claim 5 the reflective surface is defined at least in part by extending the curve section along the focal axis a predetermined amount.

18. The light assembly according to claim 1 wherein the reflective surface includes at least one reflective portion, the reflective portion defined by the curve section being rotated about the principal axis over a predetermined amount.

19. The light assembly according to claim 18 further comprising an array of LEDs and a plurality of reflective portions.

20. The light assembly according to claim 19 wherein the number of LEDs corresponds to the number of reflective portions.

21. The light assembly according to claim 20 wherein each LED includes a virtual focal point, the principal axis of each reflective portion extending through the virtual focal point of a respective LED.

22. The light assembly according to claim 1 wherein the reflective surface includes a body portion having the curve section.

23. The light assembly according to claim 22 wherein the body section is defined by extending the curve section along an axis that is perpendicular to the principal axis and to the optical output axis.

24. The light assembly according to claim 22 wherein the reflective surface includes first and second end portions, the body portion being disposed intermediate the end portions.

25. The light assembly according to claim 1 wherein the curve section includes a plurality of segments, at least one segment being defined by a mathematical equation that is different than at least one other segment.

26. The light assembly according to claim 25 wherein the segments are defined by parabolic equations.

27. The light assembly according to claim 26 wherein at least one of the segments has a principal axis that is different than at least one other segment.

28. The light assembly according to claim 26 wherein the reflective surface includes a body portion and first and second end portions, the body portion including a plurality of segments, the first end portion including a plurality of segments, and the second end portion having a plurality of segments.

29. The light assembly according to claim 28 wherein the body portion has four parabolic curve segments, each body curve segment having a different parabolic equation, the first end portion has five parabolic curve segments, each first end curve segment having a different parabolic equation, the second end portion being a mirror image of the first end portion.

30. A light assembly comprising:

an LED, the LED operable to emit light substantially along an optical output axis; and

a reflector, the reflector having a reflective surface, the reflective surface including a curve section, the curve section extended along an axis a predetermined amount;

wherein the LED is positioned such that the optical axis is in intersecting relationship with the reflective surface.

31. The light assembly according to claim 30 wherein the curve section is parabolic.

32. A light assembly comprising:

an LED, the LED operable to emit light substantially along an optical output axis, the LED having a virtual focal point, the optical output axis extending through the virtual focal point; and

a reflector, the reflector having a reflective surface, the reflective surface including a curve section, the curve section being disposed in predetermined relationship relative to a principal axis, the curve section extending substantially along the principal axis, the curve section extended a predetermined amount along an axis perpendicular to the principal axis to define at least a portion of the reflective surface, the principal axis extending through the virtual focal point of the LED, the principal axis being in intersecting relationship with the optical output axis.

33. The light assembly according to claim 32 wherein the curve section is parabolic.

FIG. 1

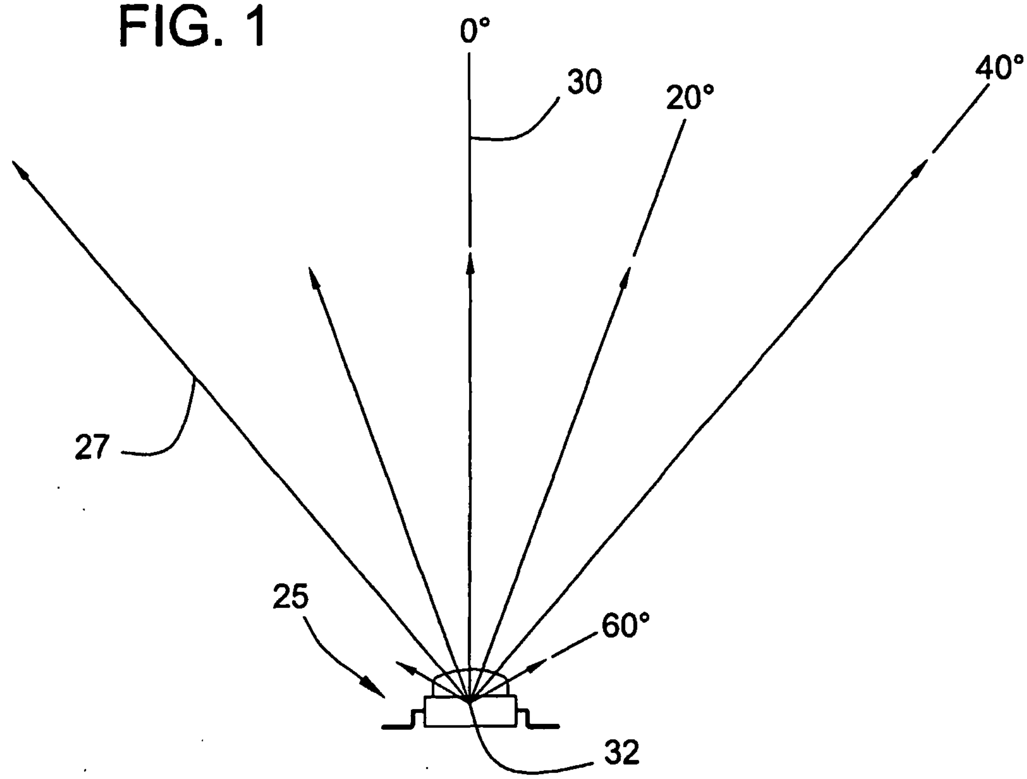

0°
30
20°
40°
27
25
60°
32

FIG. 2

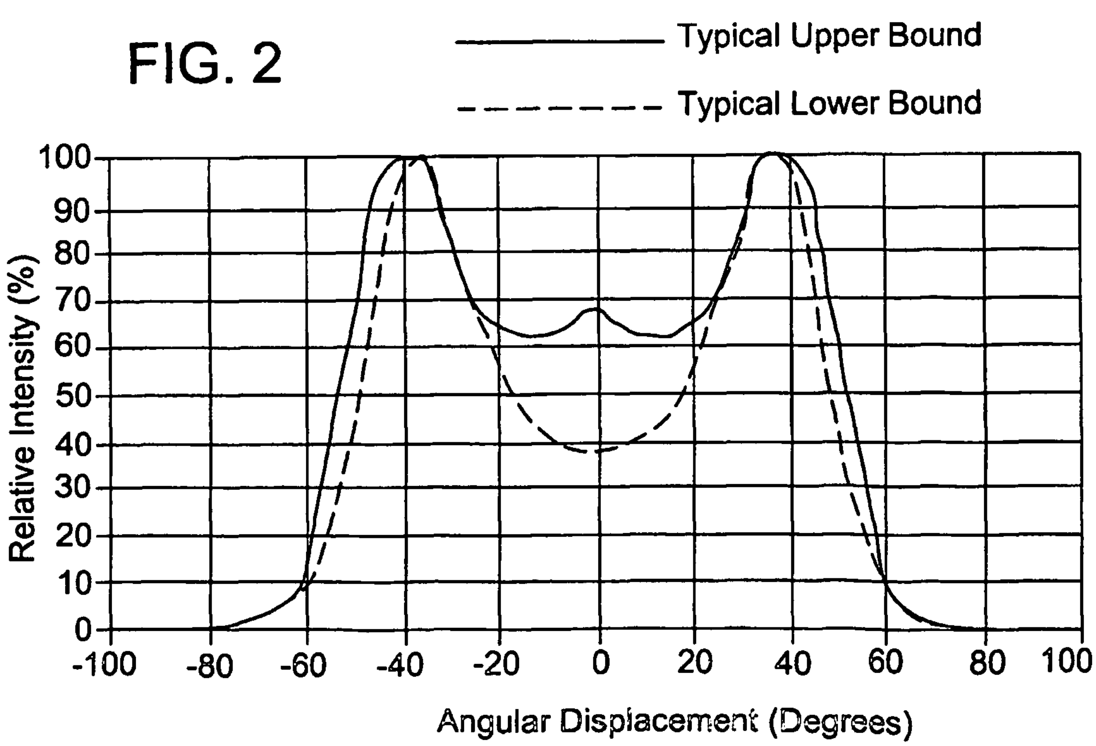

Typical Upper Bound
Typical Lower Bound
Relative Intensity (%)
100
90
80
70
60
50
40
30
20
10
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
Angular Displacement (Degrees)

FIG. 4

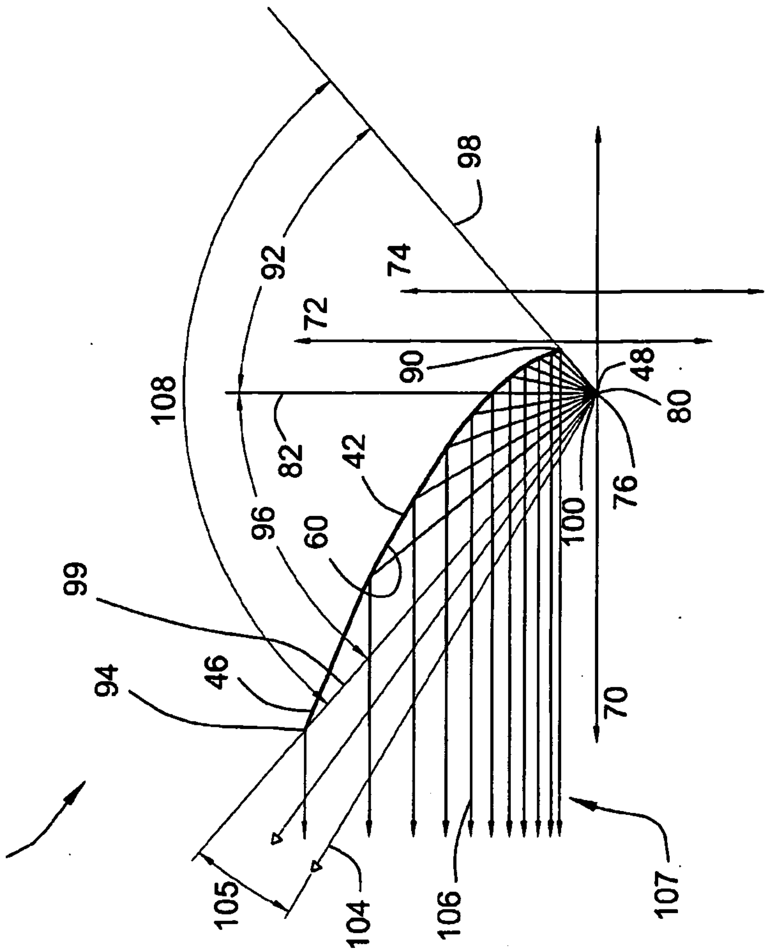
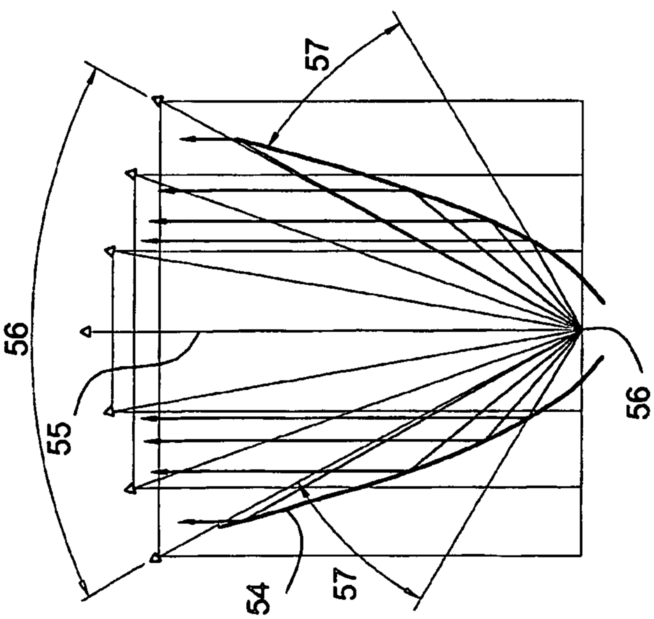


FIG. 3



PRIOR ART

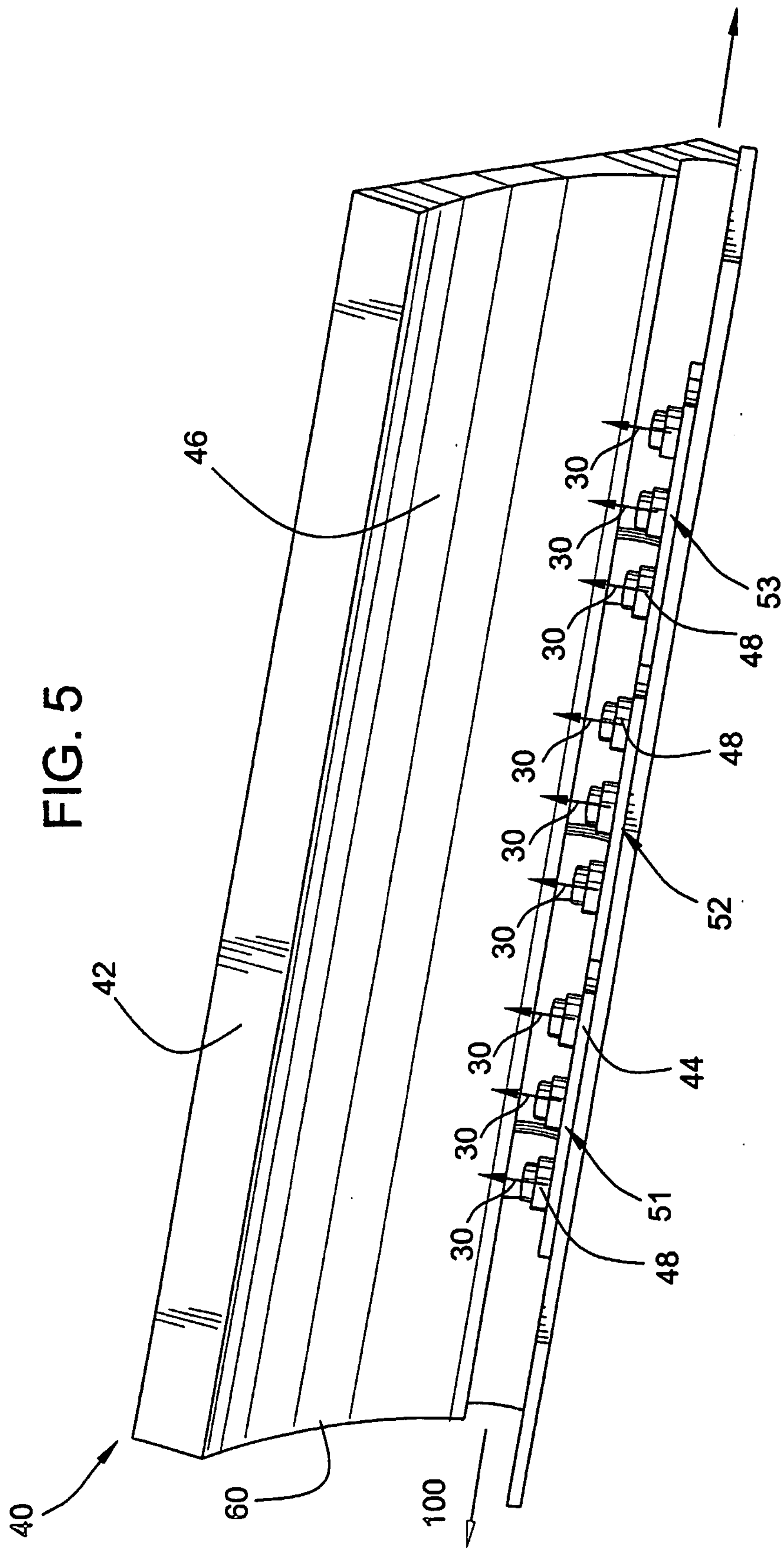


FIG. 5

FIG. 6A

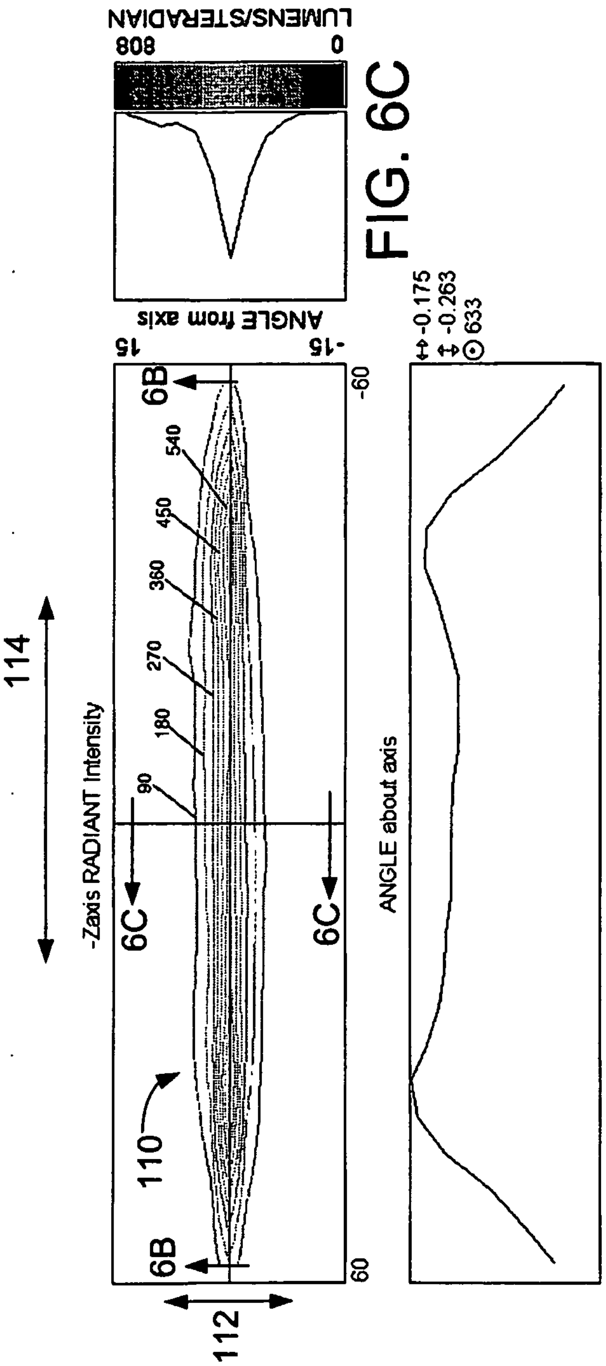
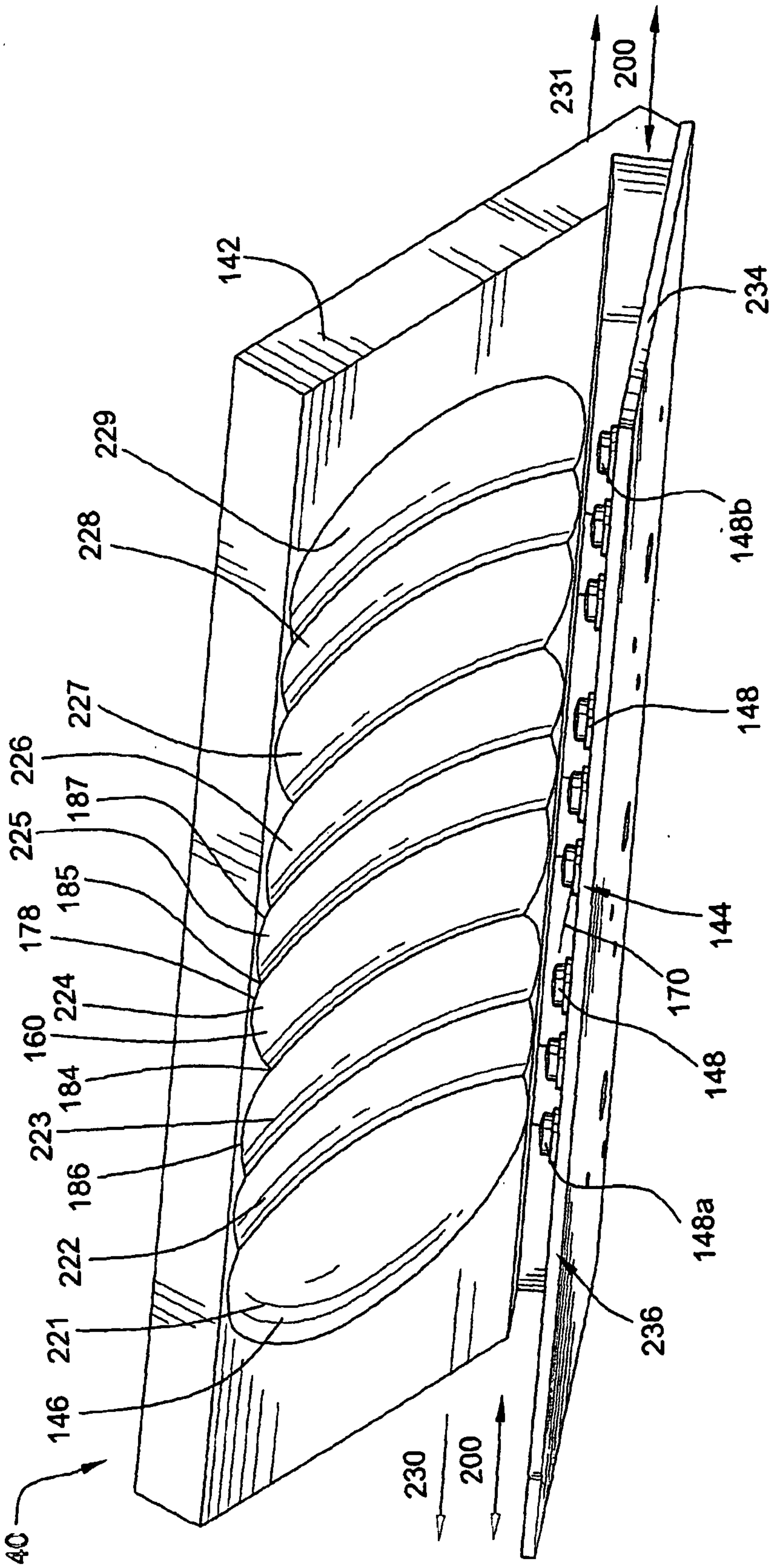


FIG. 6C

FIG. 6B

FIG. 7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148b
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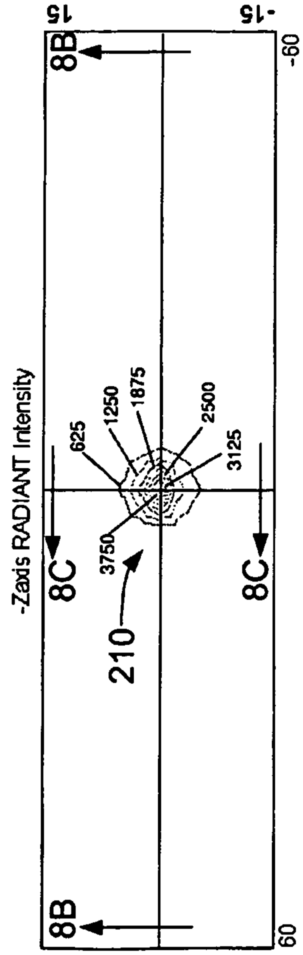


FIG. 8A

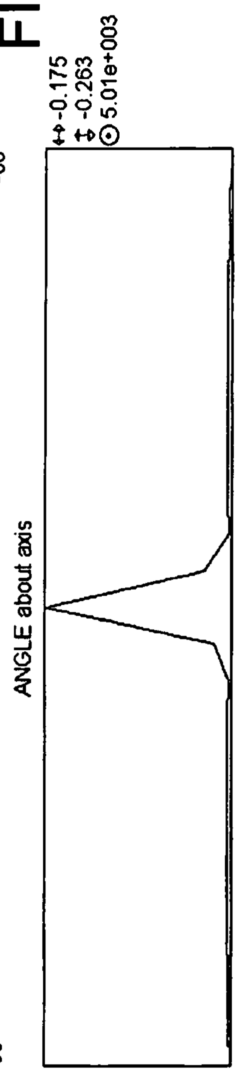


FIG. 8B

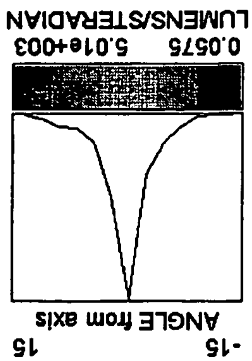


FIG. 8C

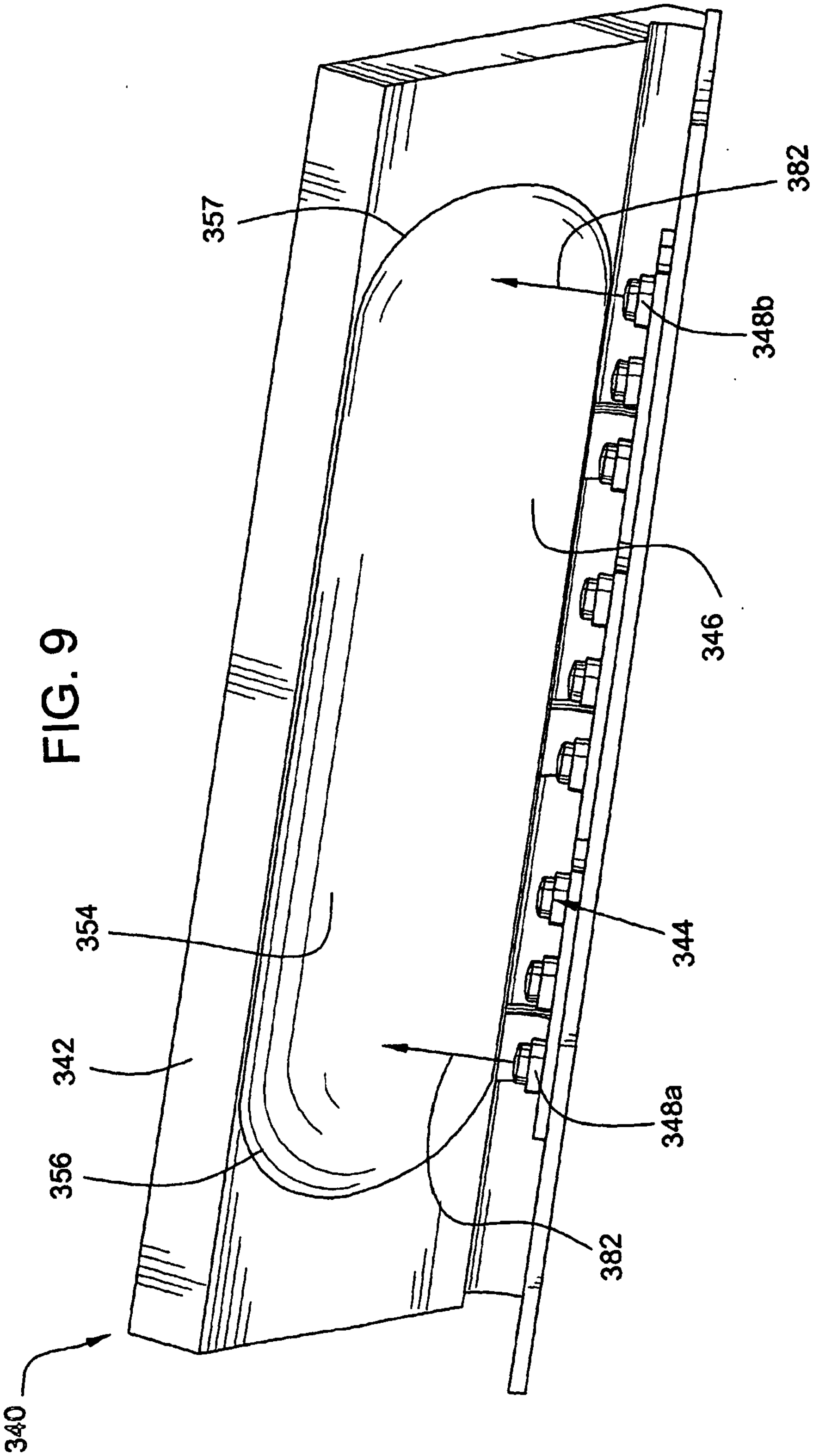


FIG. 9

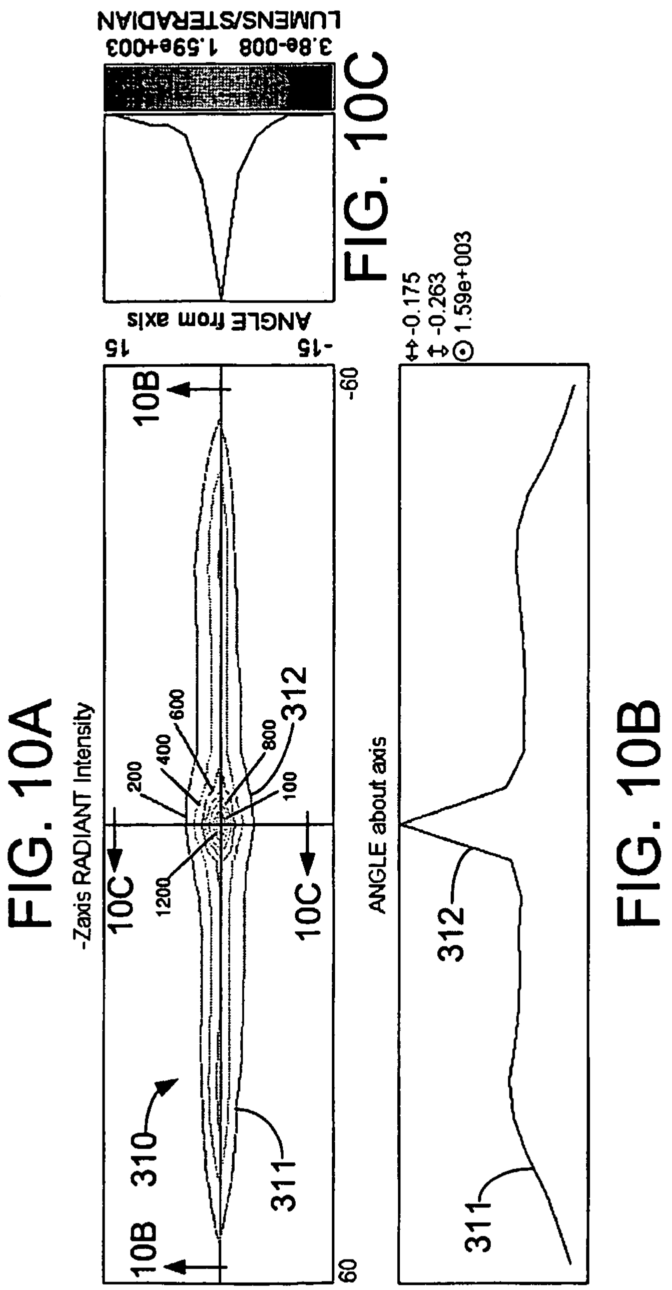


FIG. 10A

FIG. 10B

FIG. 10C

FIG. 11

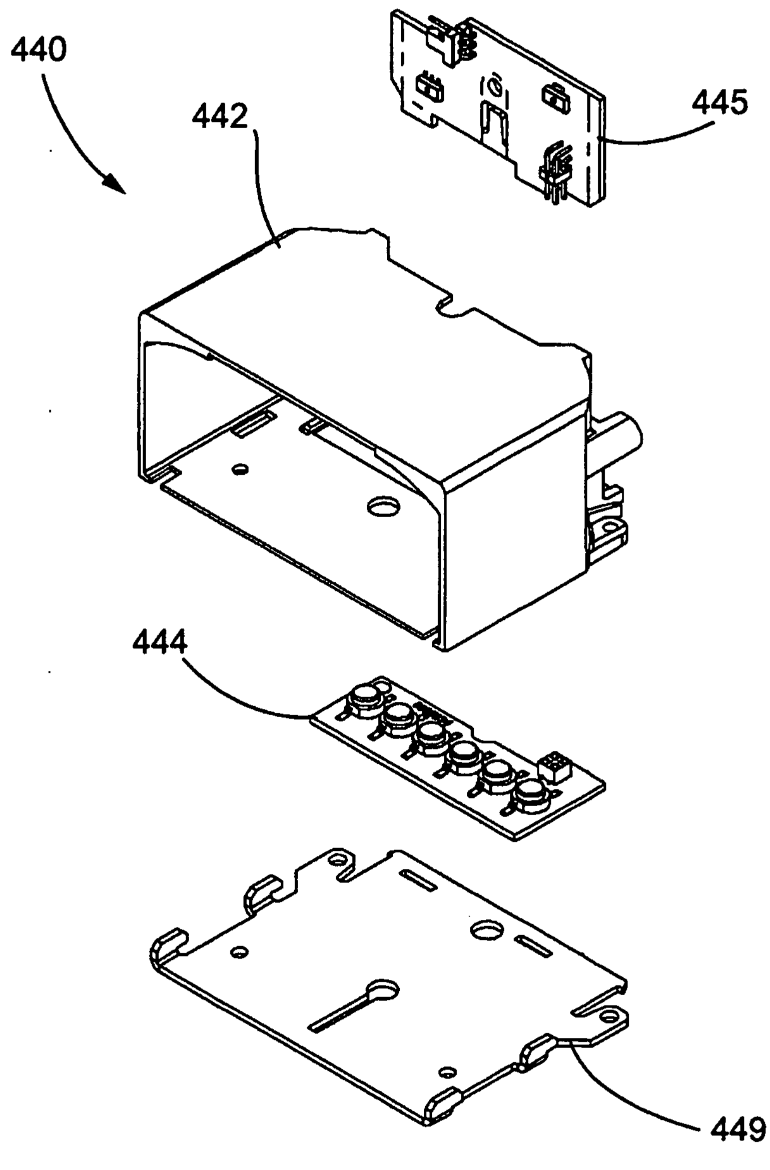


FIG. 13

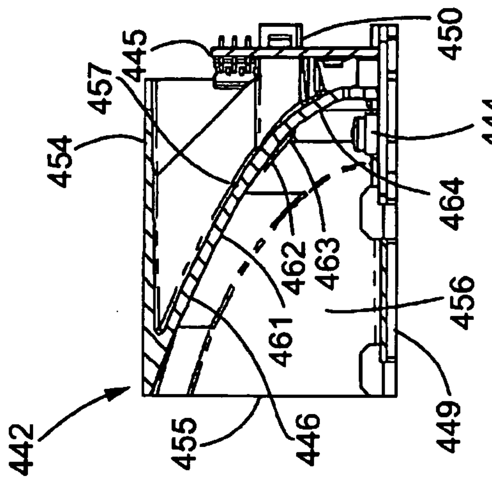


FIG. 12

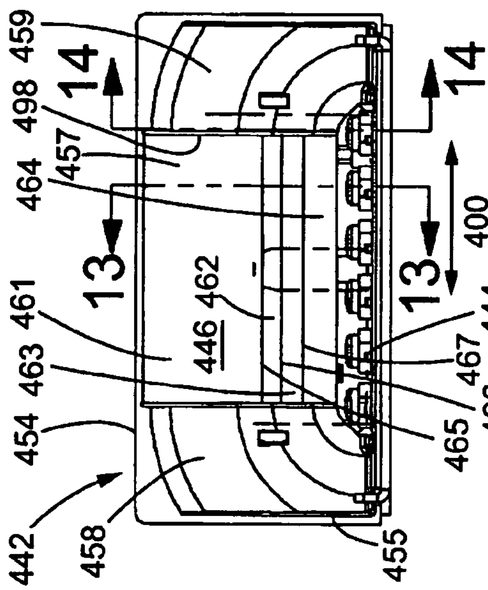
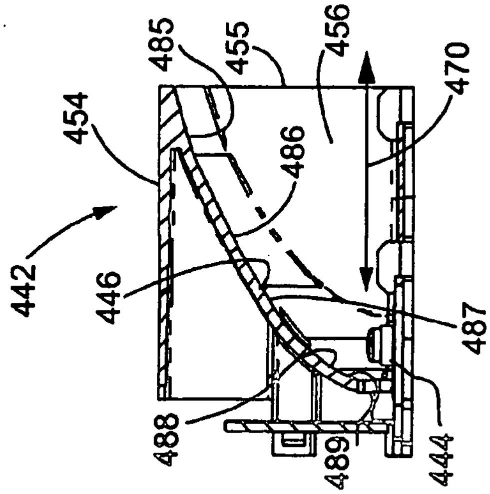


FIG. 14



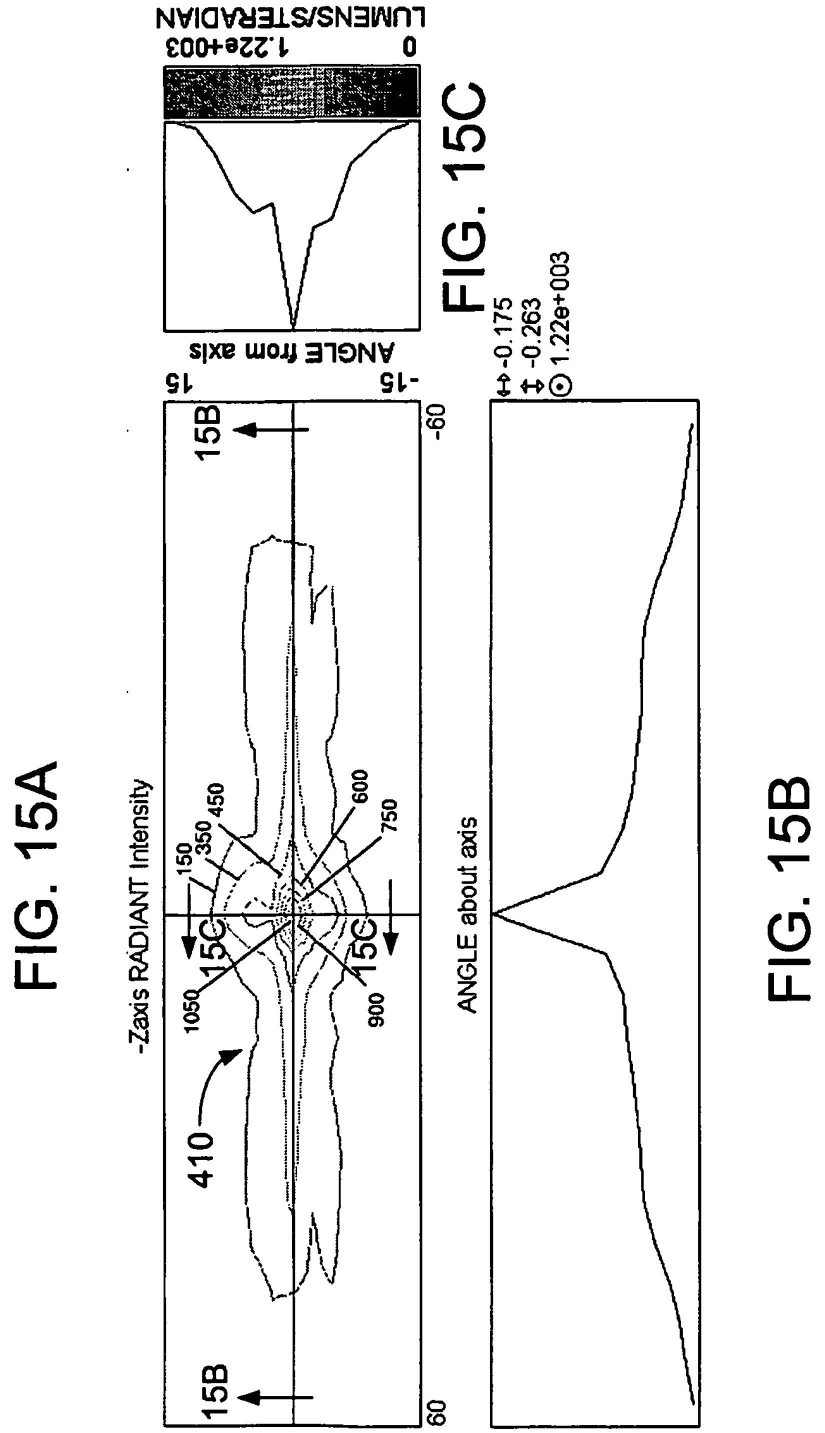


FIG. 15A

FIG. 15B

FIG. 15C

FIG. 16

RED

Combined

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10									20	50	20								
5	80	80	80	80	80	80	80	80	100	150	100	80	80	80	80	80	80	80	80
0	167	167	167	167	167	167	167	167	300	600	300	167	167	167	167	167	167	167	167
-5	80	80	80	80	80	80	80	80	100	150	100	80	80	80	80	80	80	80	80
-10									20	50	20								

Note: All values converted to equivalent steady burn values in candelas.

INTERNATIONAL SEARCH REPORT

ational Application No
PCT/US2004/033564

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F21Y101/02 H01L33/00 F21V7/09

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F21Y F21S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 471 371 A (KOPPOLU ET AL) 28 November 1995 (1995-11-28) figures 2-4,6 column 2, line 62 - column 3, line 12	1,3-9, 13-33
X	DE 101 40 692 A1 (HELLA KG HUECK & CO) 27 March 2003 (2003-03-27) figures 1-4	1,2,9-12
X	EP 1 094 271 A (ICHIKOH INDUSTRIES LIMITED) 25 April 2001 (2001-04-25) figure 2b paragraphs '0027!, '0028!	1,9, 13-16

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 January 2005	04/02/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Girard, O

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US2004/033564

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